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Comparative Study of RCC Building with Different Base Isolation System

Arun S[1], Dr. Rambha Thakur[2]

[1,2]Department of Civil Engineering, Maharshi Dayanand University, Rohtak, India

ABSTRACT

Earthquakes are one of nature greatest hazards; throughout historic time they have caused significant loss of life and severe damage to property, especially to man-made structures. On the other hand, earthquakes provide architects and engineers with a number of important design criteria foreign to the normal design process. From well established procedures reviewed by many researchers, seismic isolation may be used to provide an effective solution for a wide rangeof seismic design problems. This study presents information on the design procedure of seismic base isolation systems. Analysis of the seismic responses of isolated structures, which is oriented to give a clearunderstanding of the effect of base isolation on the nature of the structure and discussion of various isolator types are involved in this work. It presents comparative study of performance of base isolators namely Lead Rubber Bearing (LRB) and Friction Pendulum Bearing (FPB). For this study G+15 R.C building is considered and Time History analysis is carried out using ETABS software. Parameters like Storey Displacement, Storey Drift, Storey stiffness and Time period are compared for the building with base isolator and building with fixed base. Due to the presence of isolator parameters are changed in each direction (X and Y direction) as compared to fixed base building

Keywords: Seismic analysis, Time history analysis, Lead rubber bearing, Friction pendulum bearing.

INTRODUCTION

General

In the past decades, earthquake resistant design of building structures has been based on a ductility design concept. The performances of the intended ductile structures during major earthquakes have proved to be unsatisfactory and below expectation. To enhance structural safety and integrity against severe earthquakes, more effective and reliable techniques for seismic isolation design of structures based on structural control concepts are desired. Among the structural control schemes developed, seismic base isolation is one of the most promising alternatives. It can be adopted for new structures as well as the retrofit of existing buildings and bridges.

Seismic isolation, also known as base isolation in structures, is an innovative design strategy that provides a practical alternate for the earthquake resistant design of new structures and the seismic rehabilitation of existing buildings, bridges and industrial establishments.

The concept of seismic isolation is based on the premise that structure can be substantially decoupled from damaging horizontal components of earthquake ground motions. Thus, earthquake induced forces may be reduced by factors of five to ten from those that a conventional fixed-base structure would experience.

Friction pendulum bearings work on the principle of simple pendulum. The Friction pendulum bearings increase the structure's natural period by causing the building to slide along the concave inner surface of the bearing similar to a simple pendulum. Bearings can be designed to carry different magnitudes of displacement simply by adjusting the diameter and curvature of the bearing surface.

Background

Seismic isolation is also known as base isolation in structures. It is an innovative design strategy that provides a practical alternate for the earthquake resistant design of new structures and the seismic rehabilitation of existing buildings, bridges and industrial establishments.

The concept of base isolation is based on the premise that a structure can be substantially decoupled from damaging horizontal components of earthquake ground motions. Thus, earthquake induced forces could also be reduced by factors of five to ten from those that a conventional fixed -base structure would experience.

BASE ISOLATION OF STRUCTURE

Need of Base Isolation

It works on the principle of simple pendulum. When activated at the time of earthquake, the articulated slider moves along the concave surface making the structure to move in small simple harmonic motions. The Friction pendulum bearings increase the structure's natural time period by causing the building to slide along the concave inner surface of the bearing similar to a simple pendulum. The bearings filter out the experiencing earthquake forces through the frictional interface. Bearings may be designed to hold completely different magnitudes of displacement simply by adjusting the diameter and curvature of the bearing surface.

Concept of Base Isolation

The concept of base isolation can be explained by example of building resting on frictionless rollers. When the ground shakes, the rollers freely roll, but the building higher doesn't move. Thus, no force is transferred to the building due to the shaking of the ground; merely, the building doesn't experience the earthquake.

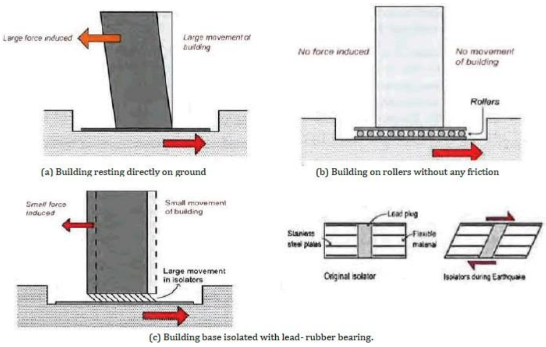

Fig 1.1 - Concept of Base Isolation

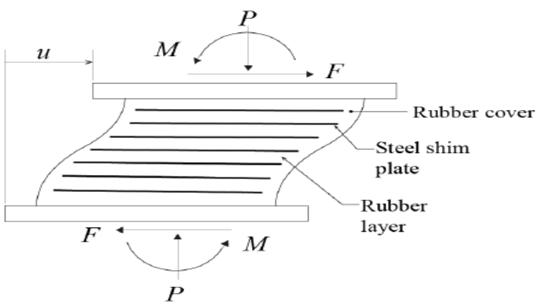

Fig 1.2- Principal of Base Isolation

Principle of Base Isolation

The principle of base isolation is very simply it changes the response of the building which allows moving the ground below the building so that the earthquake ground motion is not allowed to reached the building. Base isolation is a design approach which protects structures against damage from earthquakes by limiting the earthquake attack instead of resisting it. In base-isolated systems, the superstructure is decoupled from the ground motion by introducing horizontally flexible but vertically very stiff components at the base level of the structure. Thereby, the isolation system shifts the fundamental time period of the structure to a large value and/or dissipates the energy in damping, limiting the amount of force that can be transferred to the superstructure such that interstorey drift and floor accelerations are reduced drastically.

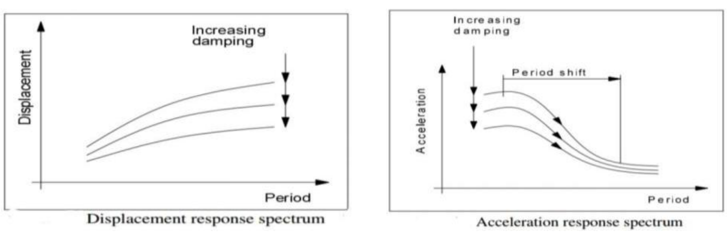

Fig 1.3 - Laminated Rubber Bearing

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TYPES OF BASE ISOLATORS

The most common use of base isolator in building is

1. Laminated Rubber (Elastomeric) Bearing.
2. Lead Rubber Bearing (LRB)
3. Sliding bearings
4. Friction Pendulum (FPS) System Bearing.

Laminated Rubber (Elastomeric) Bearing

Laminated rubber bearings are constructed of alternating rubber layers bonded to intermediate reinforcing plates that are typically steel as illustrated by the schematic of a deformed bearing. The total thickness of rubber provides the low horizontal stiffness need to achieve the period shift whereas the spacing of the steel shim plates controls the vertical stiffness of the bearing for a given shear modulus and bonded rubber area.

Lead Rubber Bearing

Lead-rubber bearings are generally constructed with low-damping elastomers and lead cores with diameters ranging 15% to 33% of the bonded diameter of the bearing. Laminated-rubber bearings are able to supply the required displacements for seismic isolation. By combining them with a lead-plug insert which provides hysteretic energy dissipation, the damping required for a successful seismic isolation system can be incorporated in a single compact component

BASIC FUNCTIONS OF LRB

(1) Load supporting function: Rubber reinforced with steel plates provides stable support for structures. Multilayer construction rather than single layer rubber pads provides better vertical rigidity for supporting a building

(2) Horizontal elasticity function (prolonged oscillation period): With the help of LRB, earthquake vibration is converted to low speed motion. As horizontal stiffness of the multi- layer rubber bearing is low, strong earthquake vibration is lightened and the oscillation period of the building is increased

(3) Restoration function: Horizontal elasticity of LRB returns the building to its original position. In a LRB, elasticity mainly comes from restoring force of the rubber layers. After an earthquake this restoring force returns the building to the original position.

(4) Damping function: Provides required amount of damping necessary. LRB mainly are of two shapes. One is conventional round and the other type is square.

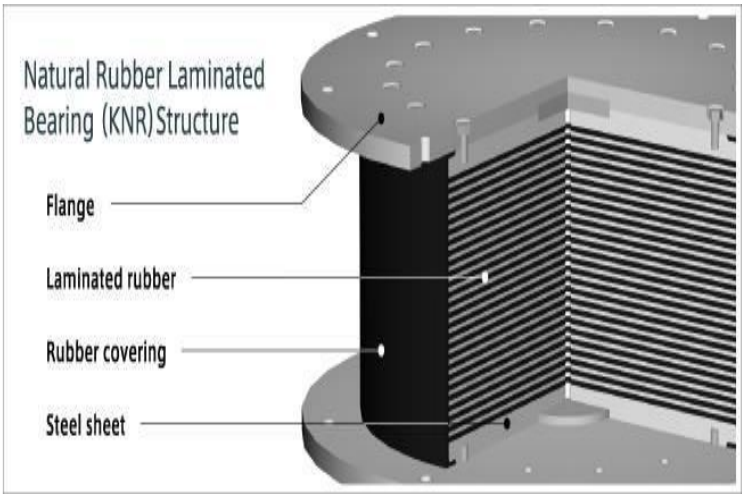


Fig 1.4 – Lead rubber bearing.

Sliding Bearing

One of the most popular and effective techniques for seismic isolation is through the use of sliding isolation devices. The sliding systems perform very well under a variety of severe earthquake loading and are very effective in reducing the large levels of the superstructure's acceleration. These isolators are characterized by insensitivity to the frequency content of earthquake excitation. This is due to tendency of sliding system to reduce and spread the earthquake energy over a wide range of frequencies. The sliding isolation systems have found application in both buildings and bridges.

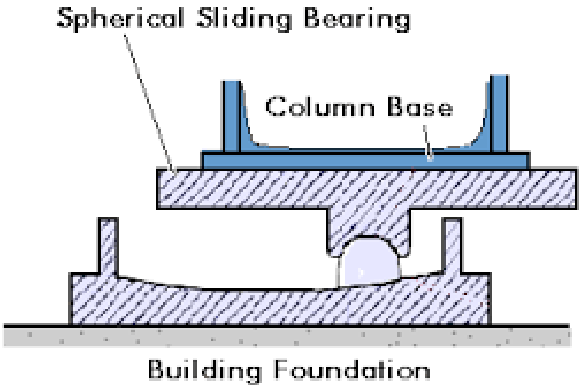


Fig 1.5 – Sliding bearing

Friction Pendulum Bearing

Seismic design of structures is attained by developing a capacity of resistance and deformability of the structure greater than the demand, which is produced due to the ground motion. When an earthquake strikes, a vibration is induced on the structure. A seismic event is manifested by the vibrations induced by the movement of the ground and which in turn produces an inertial force on the structure equal to the product of its masses for accelerations in magnitude and opposite in direction. It is important to increase the resistance of the structure with changes in the intensity of the earthquake to avoid structural damages during a seismic event.

Friction pendulum bearings (FPBs) are a modern sliding-based earthquake damage- preventing system and it is been slowly evolving important in the last decade. The first official model was designed by Victor Zayas in 1985, and FBS has become a superior safety-assuring system for modern world. Today, FPBs are available in different configurations, including single, double, and triple concave FPB systems. It consists of a bearing bottom plate coated with a sliding material (Teflon), an articulated slider and a bearing top plate. FPB's are provided over the pile cap or column head upon which the superstructure rests. Thereby detaching the superstructure from the substructure and filtering out the earthquake forces affecting the super structure. With the implementation of the FPB's, factors such as base shear, joint acceleration, story drift and displacement of the structure during an earthquake are lowered and hence building is to be designed only for wind and gravity loads.

There are two stages in the performance of an FPB, a static and a dynamic phase, distinguished by the friction in the sliding interphase. When the lateral forces acting on the structure is below the frictional resistance offered, FBP's acts as a rigid connection transferring the total force between the superstructure and the substructure. But when the excitation force is greater than the static frictional force, the system gets activated. The supported structure moves similar to a simple pendulum, thereby dissipating he hysteretic earthquake force by friction.

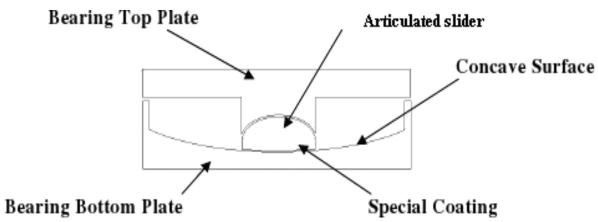


Fig 1.6 – Cross section of friction pendulum bearing

CONCEPT OF FRICTION PENDULUM BEARING

Friction Pendulum Bearings work on the same principle as a simple pendulum. When activated during an earthquake, the articulated slider moves along the concave surface causing the structure to move in small simple harmonic motions.Similar to a simple pendulum, the bearings increase the structures natural period by causing the building to slide along the concave inner surface of the bearing. This lateral displacement greatly reduces the forces transmitted to the structure even during eight strong magnitude earthquakes. This type of system also possesses a re-centering capability, which allows the structure to center itself, if any displacement is occurred during a seismic event due to the concave surface of the bearings and gravity.

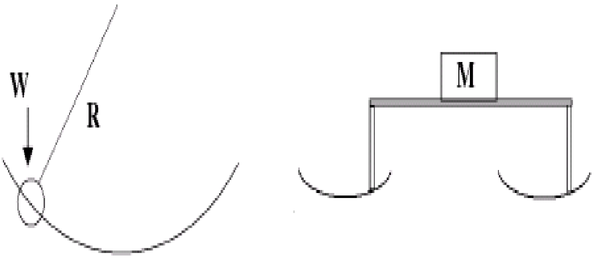


Fig 1.7- Concept of sliding pendulum motion

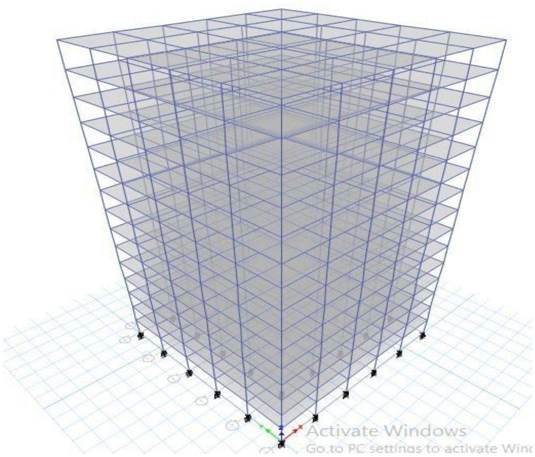
METHODOLOGY

Modeling is carried out using **ETABS 2019**.

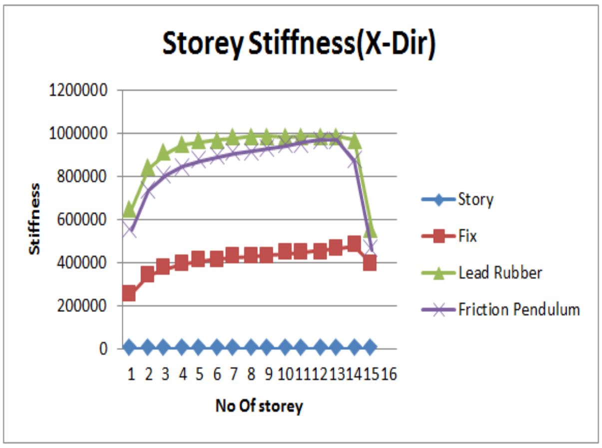
Structural Properties-

Seismic Zone	Zone 5
No. of storeys	G+15
Height of Building	48 mt
Each floor height	3 mt
Live Load	3 kN/m^2
Wall load	13.8 KN/m^2
Grade of concrete	M25
Grade of Steel	HYSD 415
Size of Beam	450x600 mm
Size of Column	450x600 mm
Thickness of Slab	125 mm

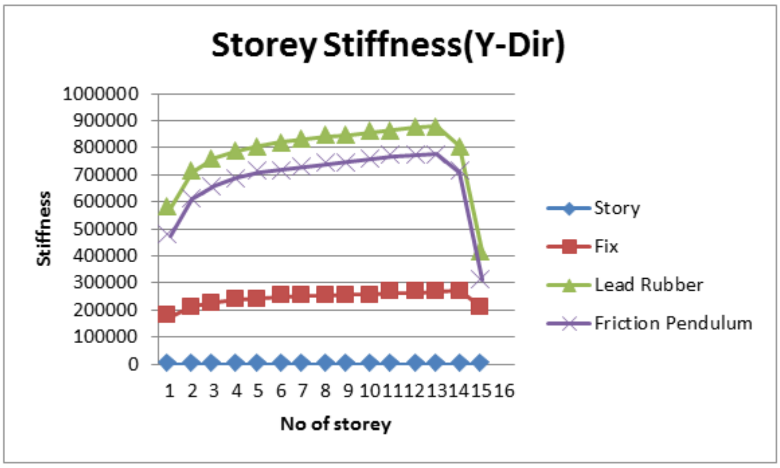
In the present study G+15 storey building is considered and linear time history has been applied. The finite element analysis has been done using ETABS 2019. Comparison of a regular building with a fix base with different base isolators that is Lead Rubber Bearing (LRB) and Friction Pendulum Bearing (FPB) has been done. Various parameters such as storey displacement and story drift have been calculated and compared.



Model of the Regular Building



The study shows that the nature of all the models is different after seismic disturbances. Building having Lead rubber bearing shows the best result and gives a maximum value of story stiffness in X direction as compared to other models.



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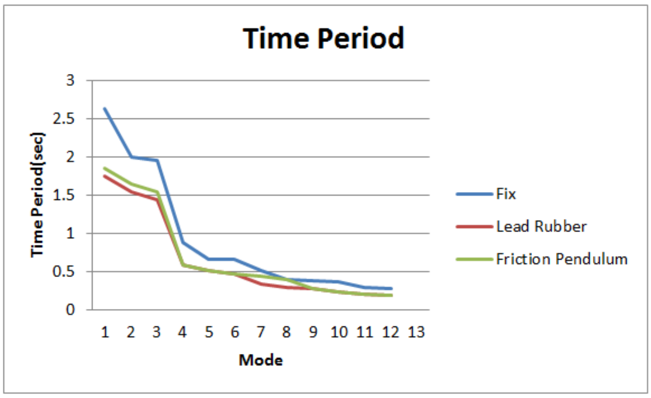

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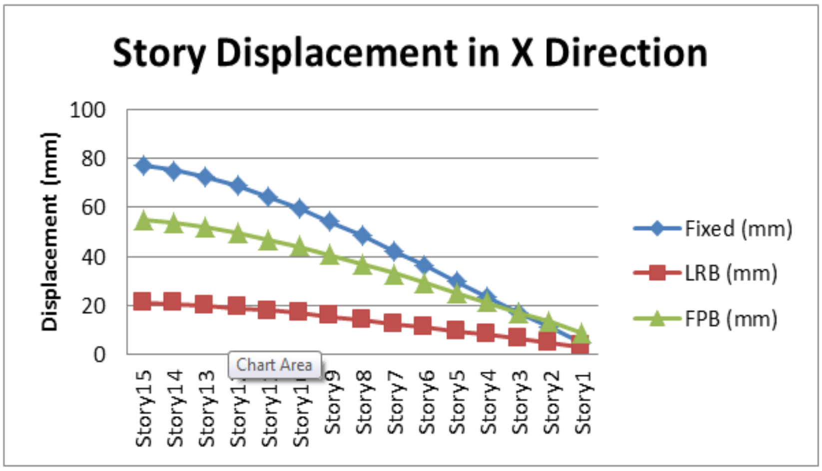

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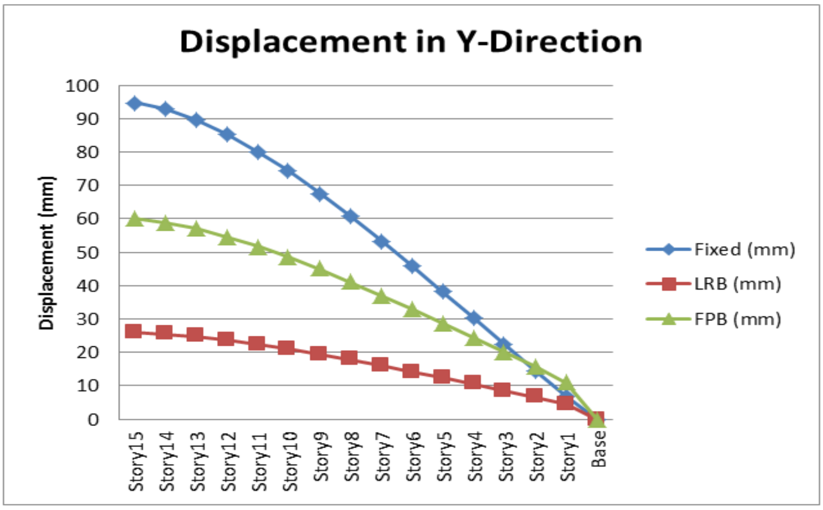
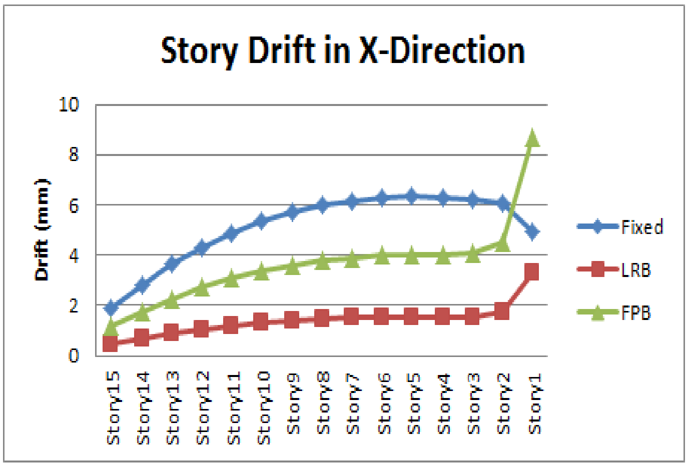


Different after seismic disturbances. Building having Lead rubber bearing shows the best result and gives a minimum value of story drift in X direction as compared to other models.



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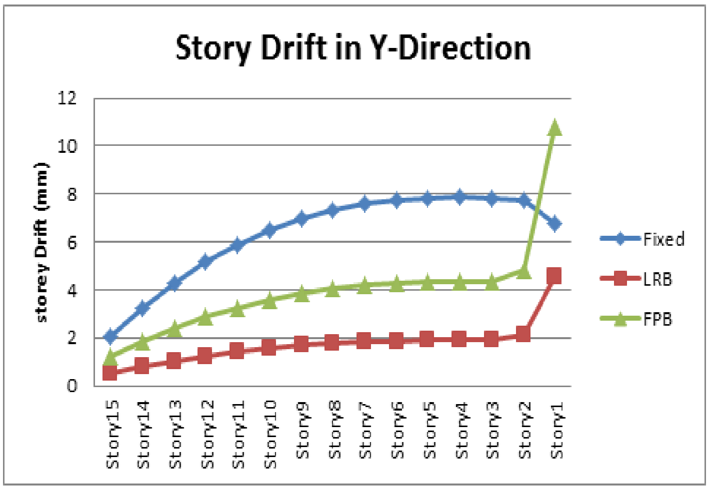

CONCLUSIONS

- It can be concluded that the story stiffness both in X and Y directions is the maximum for Lead rubber bearing, lesser in friction pendulum and minimum for fixed base.
- It can be concluded that the natural time period is theleast in Lead rubber bearing, larger in friction pendulum and the most for fixed base.
- It is concluded that Lead rubber bearing is the best model as compared to friction pendulum and fixed base.
- It can be concluded that the story displacement both in X and Y directions is the least in Lead rubber bearing, larger in friction pendulum and the most for fixed base.
- It can be concluded that the story drift both in X and Y directions is the least in Lead rubber bearing, larger in friction pendulum and the most for fixed base.
- It is concluded that Lead rubber bearing is the best model as compared to friction pendulum and fixed base.

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